

**The Synergistic Effect of Latrines and Increased Usage of Water  
on Growth of Infants in Rural Lesotho**

by

**Steven A. Esrey  
Jean-Pierre Habicht  
and  
George Casella**

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Steven A. Esrey<sup>2</sup>, Jean-Pierre Habicht<sup>3</sup>, George Casella<sup>4</sup>

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2. School of Dietetics and Human Nutrition. Macdonald College of McGill University, 21,111 Lakeshore Road, Ste. Anne de Bellevue, Canada H9X 1C0.
3. Division of Human Nutrition, Cornell University, Ithaca, NY 14853.
4. Biometrics Unit, Cornell University, Ithaca, NY 14853.

### ABSTRACT

The effects of water and sanitation, alone or in combination with each other, on infant growth were examined. The data on 119 infants were collected from 20 villages in rural Lesotho between July, 1984 and January, 1985. The effect of sanitation was dependent on whether or not families increased their use of water during the warm, wet season. The reverse was also true. Infants whose families had latrines and increased their per capita water usage in the warm months grew 1 kg and 2 cm more than infants with only one or none of these positive factors. Infants gained 1.031 kg (0.420,1.642) and 2.028 cm (0.523,3.533) more, when both positive factors were present, compared to only increasing water usage. Similarly, infants gained 1.106 kg (0.484,1.728) and 2.076 cm (0.559,3.593) more if both factors were operating compared to infants whose families had only a latrine. These effects were controlled for potential confounding factors. Water supply programs should emphasize use of more water for personal hygiene, and sanitation programs should install facilities where water usage is high or has been increased due to an educational program.

## INTRODUCTION

The literature on the health benefits following improvements in water supplies and sanitation is mixed (Esrey and Habicht, 1986). Positive and negative findings have been reported. Some of the negative findings are due to improper implementation of the intervention, lack of usage of the facilities, and the design and measurement problems of the evaluation. It appears, however, that in better studies discrepancies between positive and negative findings can be explained by differences in environmental conditions (Burger and Esrey, 1990). That is, various types of intervention in different areas, with different levels of environmental contamination, and other risk factors, may result in different relative impacts (Esrey et al, 1985).

For instance, in Malaysia, toilets were associated with a larger decrease in infant mortality rates among non-breast-fed infants than among breast-fed infants (Habicht et al, 1988). Partially breast-fed infants also had lower mortality rates when a toilet was present compared to no toilet, but the reduction in the mortality rate was not as large as it was for the non-breast fed infants (Butz et al, 1984). In these same data the presence of toilets was associated with a larger reduction in infant mortality rates among illiterate than among literate women (Esrey and Habicht, 1988). In Fiji (Yee, 1984) flush toilets were associated with significantly better child nutritional status among the low income group, but to a lesser extent among the high-income group.

Similarly, in Malaysia access to improved water supplies reduced infant mortality rates among non-breast-fed infants, but not among breast-fed infants (Butz, 1984). Piped water was also reported to lower infant mortality rates more among literate than among illiterate mothers in the Malaysian sample (Esrey and Habicht, 1988). The use of water for domestic hygiene practices also had a greater impact on diarrhea when crowding was present in Haitian households; increased use of water was associated with less diarrhea (Thacker, 1980).

Two inferences may be drawn from the above studies. First, interventions to improve sanitation and to increase use of water for better domestic hygiene practices can improve child health, particularly when exposure to the infectious agents of diarrhea is high (Esrey, et al, 1985). Second, multiple interventions to reduce exposure to pathogenic agents of diarrhea are more likely to produce health impacts than single interventions without complementary inputs (Briscoe, 1984).

Data from an evaluation of an intervention to improve water supplies in rural Lesotho provide an opportunity to examine the second issue. The impact on child growth from the presence or absence of latrines and the different levels of water usage can be analyzed by testing for a statistical interaction between these two factors. One can hypothesize, a priori, that a child's growth will be better among families whose level of both family sanitation facilities and per capita usage of water are higher than among other families with inadequate levels of these

factors, and higher than would be expected given the presence of only sanitation or only high water usage. Infants exhibit the greatest potential for better growth because growth faltering begins by 4-6 months of age in this population (Esrey, 1987). Furthermore, it has been reported that water quantity was more important among infants compared to older children (Esrey, 1988). Thus, only infants will be examined in this paper.

#### MATERIALS AND METHODS

The infants (n=119) whose data were analyzed in this report were studied as part of a health impact evaluation of a rural water supply intervention in Lesotho. These infants 1-12 months of age at the start of the study, came from twenty rural villages in the lowlands or foothills. The villages were situated in four of the country's ten administrative districts where 50% of the rural population reside. Ten of the villages had access to an improved and functioning community water supply. The other villages, which relied on traditional sources, were paired with the improved villages on the following characteristics: district, village size, and presence or absence of schools/clinics.

Data were collected in two five-week long periods six months apart, July-August, 1984 and January-February, 1985. During period I, the cool, dry season mothers answered questions about socio-economic characteristics of the household and domestic hygiene practices and children were measured for length and weight. During period II, the warm, wet season, children were

measured for length and weight and water usage was measured again.

The outcome variable, infant growth, was calculated by regressing each infant's period II length or weight on his/her initial length or weight value. Residuals from these regressions were used as the growth outcomes (Esrey et al, 1990).

The amount of water collected daily per person was estimated during periods 1 and 2. Pictures of buckets commonly used to collect water were shown to mothers, who recalled how often each bucket was filled the previous day to determine total household water usage in liters. This figure, divided by the number of household members, estimated the amount of water used in liters per capita per day (lcd). Infants were then categorized into one of three water usage groups: <8 lcd, 8-17 lcd, and >17 lcd. The cut-points for these groups were created because 8 liters represented the average per capita daily water use of the sample and 17 liters represented the amount of water easily obtained given the design of the improved water supplies and represented only 2 additional 20 liter buckets per family per day, above the average. Thus, the cut-points have public health implications in the Lesotho context. Infants were then classified further according to the changes in the family per capita water usage from period 1 to period 2. If the infant's family moved up one or two classifications (e.g. from <8 lcd to 8-17 lcd or >17 lcd), infants were classified as increased users. If the classification dropped or stayed the same infants were classified

into the non-increased group. During the dry season in Lesotho, temperatures often drop below freezing during the evening and night, and during the day temperatures may only reach 10° Celsius. Bacteria have less chance of surviving and being spread by rain in the dry winter months (period 1) than in the wet summer months (period 2). Diarrhea rates were higher in the warm, wet summer months than at the end of the cool, dry winter months and the beginning of summer. Thus, one can predicted that using more water as the summer approached would be of benefit to infant growth. Children were also classified as to whether or not the family owned a latrine.

A number of variables were controlled in the analyses: district of residence, intervention group, remittances sent from a family member living out of the village, natural log of major household expenditures, number of pieces of agricultural equipment owned, number of major household possessions, crowding (people/room), mother's occupation (farm own land, farm another's land, knit/sew, brew beer), maternal literacy, maternal marital status, whether or not the mother was pregnant, maternal bathing frequency, parity, child's sex, infant's age in months, and whether or not the child was bottle fed. Thus, the effects on infant growth reported below are adjusted effects after controlling for the above variables.

The effect of water quality was analyzed previously and was found to have an insignificant effect on infant and child growth (Esrey et al, 1986). Therefore, water quality is not controlled



in the analyses below. The effect on growth was different between the children from the improved and unimproved groups; the children from the unimproved group grew better. This difference has been controlled in the analyses below.

Statistical analyses were done using SYSTAT version 3.0 (Wilkerson, 1987) on an AT&T 6300 Personal Computer. Once the full model was estimated, a reduced model, which included only those variables contributing to the overall variance, was run. If a variable's 80% confidence interval included zero, that variable was dropped from further analyses. Only the results from the reduced model are presented below. All confidence intervals are at the 95% level, and two-tailed.

## RESULTS

### Latrines

Twenty-two percent of infants came from families that used simple pit latrines. Unadjusted growth differences showed that children whose families possessed a latrine grew 0.251 cm (-0.373, 0.875) more in length and 0.177 kg (-0.088, 0.442) more in weight than children whose families did not have a latrine.

### Water quantity

The installation of the improved water supplies did not result in the use of more water on a per capita basis compared to the unimproved group. Inhabitants from both groups of villages, improved and unimproved, averaged 9.6 and 7.8 liters per capita

per day during periods 1 and 2, respectively. However, people used different amounts of water, regardless of the type of village in which they resided. Per capita use of water reached a high of 35 liters.

The association between growth and water usage was stronger during period II than period I, although the 95 percent confidence intervals included zero. Each per capita liter increase during period 1 was associated with -0.022 cm (-0.060, 0.016) in length gain and -0.002 kg (-0.018, 0.014) in weight gain. The figures for growth and water usage during period II were 0.035 cm (-0.016, 0.084) and 0.019 kg (-0.003, 0.041).

#### Effect of changes in water usage over seasons

Nineteen per cent of the sample came from the increased water usage group, which went from an average of 5.7 liters per capita per day during period I to 12.7 liters per capita per day during period II. The corresponding figures for the non-increased group, which comprised 8 per cent of the sample, were 10.5 and 6.6 liters per capita per day, respectively. The non-increased group was further divided into a decreased and no change group. The decreased group, 31 percent of the sample, averaged 15.8 and 6.6 lcd in periods I and II, respectively. The no change group, 50 per cent of the sample, averaged 7.4 and 7.2 liters per capita per day during the first and second period, respectively. The increased users gained 0.230 cm (-0.423,

0.883) and 0.317 kg (0.044, 0.590) more than the non-increased group.

#### Synergism between changes in water usage and latrines

The majority of the sample, 62 per cent, did not have a latrine nor did they increase water usage from period I to period II (table 1), and less than 4 per cent of the sample had a latrine and increased water usage. One third of the sample had either a latrine (18.5 per cent) or increased water usage (16.0 per cent). Overall the increased water group more than doubled their per capita use of water from period I to II. This was true regardless of whether or not a latrine was present. The non-increased group decreased their water consumption by almost 40 percent, again regardless of latrine ownership. Overall, a latrine was associated with a 19 percent reduction in water usage. In the non-increased group the reduction was 35%, but in the increased group the increase was more than 2.5 times greater in period II compared to period I.

The analysis of these different combinations indicated a synergism between water and sanitation on weight (table 2) and length gain (table 3). The effect of having a toilet or increasing water usage was of benefit only if the other positive factor was present. This was equally true for weight and length gain.

For weight gain (table 2), the effect of increasing water usage was most apparent if a latrine was present. The effect of

increasing versus not increasing water usage was 1.031 kg (0.420, 1.642). In the absence of a latrine the effect was inapparent; the difference was 0.150 kg (-0.250, 0.550). Similarly, the effect of having a latrine became apparent in concert with increasing the amount of water used from period I to period II. Among infants in the increased water group, the effect of having a latrine increased weight gain by 1.106 kg (0.484, 1.728). The weight difference between having and not having a latrine in the non-increased water usage group was 0.180 (-0.093, 0.453). Six month weight gain was more than 1 kg greater if both positive factors were present than if only one or none of the factors were present.

The synergism between increased usage of water over seasons and the presence of latrines was also found for infant length gain (table 3). The difference in length gain between infants with and without a latrine in the increased water usage group was 2.076 cm (0.559, 3.593). The effect on length gain of having versus not having a latrine if water usage was not increased was -0.261 cm (-0.951, 0.429). Increasing the use of more water over seasons was associated with a small decrease in length gain of -0.309 cm (-1.005, 0.387) compared to not increasing water usage if no latrine was present and by 2.028 cm (0.523, 3.533) if a latrine was present. Both positive factors occurring together resulted in an additional 2.0 cm growth than if only one factor was present or both absent.

## DISCUSSION

The combination of the presence of latrines and the use of more water, particularly during the wet season, resulted in better child growth. The combination of latrines and use of more water complemented each other because the beneficial effect of each factor was only realized in the presence of the other.

Latrines can break the transmission of fecal-oral pathogens by not allowing the fecal-borne infectious agents to come into contact with the environment. The effectiveness of latrines in reducing diarrhea has been reported in numerous studies (Esrey and Habicht, 1986). In the absence of proper fecal disposal, pathogens gain access to the environment, and they can be ingested from a variety of sources. Using water for personal and domestic hygiene should, therefore, reduce the quantity of pathogens ingested. This was the case for Giardia lamblia (Esrey et al, 1988). Thus, it is plausible that better growth resulted from the combination of latrines and the use of more water by interrupting and reducing the transmission of pathogens.

Potential confounding variables were excluded from the analyses to remove multicollinearity and to increase precision. If the effects of the variable's 80 per cent confidence interval on child growth included zero, these variables were excluded from the analyses. Excluding these variables did not change the results compared to the full model, which included all of the factors listed in the methods section.

The average daily amount of water used per person was low. The average water use was similar to that reported by others in Lesotho (Feachem et al, 1978; Engler, 1984). In a previous study (Feachem, 1978), water collection was observed at the source and mother's reported using about 9 liter per capita per day for domestic uses. A more recent study (Engler, 1984) metered taps and handpumps, and reported an average of 8 lcd in similar villages. All of these studies reported a wide range of water use, reaching 35-50 liters per capita per day in several instances. Thus, the use of pictures to measure per capita water use proved to be a reliable method.

Only 4 infants came from families with both positive factors. Despite few children significant and important differences in growth were observed. Because only 4 children were found in the cell, their records were scrutinized for difference between other children that could bias results. No differences were found between these children and the other children in the sample regarding the socioeconomic variables. The ages of these 4 children ranged from 2-12 months (average of 5.3) compared to a range of 1-12 months (average of 7.4) for the rest of the sample. The regression analyses provided nearly identical results with and without age included. Errors in anthropometric measurements were very small (Esrey, 1987), and are unlikely to bias results. Infants were measured twice, and if the average of the measurements did not agree with head and arm circumference measurements, also done in duplicate, the

infants were remeasured the same day. Furthermore, period II measurements of children were without knowledge of period I measurements and without knowledge of the hypotheses of the study. The possibility that these four children consumed a different diet than the others cannot be ruled out. Detailed dietary information should be collected in future studies of this kind.

It is unlikely that bias in the collection of these data could explain these results. First, no bias in the collection of anthropometric data was observed. Second, the information on latrines was collected by survey and observed by enumerators. Third, the data for the method of collecting water quantity was verified by others, and increases in per capita water usage among these four infants were similar to increases among the infants without latrines. Fourth, the other variables were distributed similarly across the comparison groups and were controlled in the analyses.

It has been hypothesized that single interventions to improve health may fail to produce measurable health benefits because the necessary and sufficient conditions, if not implemented or present at the same time, may mask the potential benefit of a single intervention (Briscoe, 1984). Averaging the effects of a single factor across different levels of a second factor may hide real benefits that exist in a population. Thus, specific interventions to improve health must either be

accompanied by synergistic interventions or be implemented in an appropriate setting whereby health benefits may be realized.

A strong positive effect was found between level of water usage and child growth, much greater than the association found between drinking water quality and child health in this sample (Esrey et al, 1986). Therefore, efforts should be made to encourage people to use more water, and less attention should be paid to supplying clean, uncontaminated, water. Because very few children come from families with both positive factors, increased water usage and latrines, a great improvement in child growth could be achieved by installing latrines and encouraging families to use more water for personal and domestic hygiene. Based on the results above, one can predict that in rural Lesotho increasing the use of water by only one or two 20 liter bucket per family per day should result in significant health impacts. Furthermore, the results suggest that efforts to encourage people to use more water should be accompanied by the installation of latrines because a synergism was found between these factors. The programmatic implications are that the current rural water supply program should encourage the use of more water and the latrine program should give priority to installing latrines in areas where water usage is already high or has increased as the result of an educational program.



## REFERENCES

1. Esrey SA and Habicht J-P. Epidemiologic evidence for health benefits from improved water and sanitation in developing countries. Epidemiologic Reviews 1986; 8:117-128.
2. Burger SE and Esrey SA. Water and sanitation: health and nutrition benefits to children. Cornell University, Food and Nutrition Policy Program (In press) 1990.
3. Habicht J-P, Davanzo J, Butz WP. Mother's milk and sewage: their interactive effects on infant mortality. Pediatrics 1988; 81(3):456-61.
4. Butz WP, DaVanzo J, Habicht J-P. Environmental factors in the relationship between breastfeeding and infant mortality: the role of sanitation and water in Malaysia. American Journal of Epidemiology 1984; 119:516-25.
5. Esrey SA, Habicht J-P. Maternal literacy modifies the effect of toilets and piped water on infant survival in Malaysia. American Journal of Epidemiology 1988; 127(5):1079-87.
6. Yee V. Household level correlates of child nutritional status in Fiji. Master's Thesis. Cornell University, Ithaca, NY: 1984.
7. Thacker SB, Music SI, Pollard RA et al. Acute water shortage and health problems in Haiti, Lancet 1980; 1:471-3.
8. Esrey SA, Feachem RG, Hughes J. Interventions for the control of diarrhoeal diseases among young children:

- improving water supplies and excreta disposal facilities.  
Bull WHO 1985;63:757-72.
9. Esrey SA. The effect of improved water supplies and sanitation on child growth and diarrheal rates in Lesotho. Ph. D. Thesis, Cornell University, Ithaca, NY, 1987.
  10. Esrey SA, Habicht J-P, Latham MC.et al Drinking water source, diarrheal morbidity, and child growth in villages with both traditional and improved water supplies in rural Lesotho, Southern Africa, American Journal of Pubhlic Health 78:1451-1455, 1988.
  11. Briscoe J. Intervention studies and the definition of dominant transmission routes. American Journal of Epidemiology 1984; 120:449-55.
  12. Esrey SA, Casella G, Habicht J-P. The use of residuals for longitudinal data analysis: the example of child growth. American Journal of Epidemiology. 1990; 131(2):365-372.
  13. Esrey SA, Habicht J-P, Casella G., et al. Infection, diarrhea and growth rates of young children following the installation of village water supplies in Lesotho. Paper presented at the 22nd Annual Conference of the American Water Resources Association, International Conference on Water and Human Health, International Symposium on Water-Related Health Issues, Atlanta, Georgia, November 9-14, 1986.
  14. Wilkerson L. The system for statistics (Version 3.0). SYSTAT, Inc. Evanston, IL 1987.

15. Esrey SA, Collett J, Miliotis MD, et al. The risk of infection from Giardia lamblia due to drinking water supply, use of water, and latrines among preschool children in rural Lesotho. International Journal of Epidemiology 1988; 18:248-53.
16. Feachem RG, Burns E, Cairncross S, et al. Water, health and Development. London: Tri-Med Books, 1978.
17. Engler M. Water consumption and hydraulics in village water supplies in Lesotho. NADEL, ETH-Zurich, Switzerland. 1984.

Table 1

Changes in per capita water usage from period I to II  
depending on latrine ownership and water usage group  
for 119 infants in rural Lesotho

		Latrine ownership		Average
		No	Yes	
Increased water group	No	10.6 - 6.6 <sup>α</sup> (74) <sup>β</sup>	10.4 - 6.8 (22)	10.6 - 6.6
	Yes	5.9 - 12.5 (19)	5.1 - 13.3 (4)	5.7 - 12.7
Average		9.6 - 7.8	9.6 - 7.8	

α. Liters per capita per day from period I - period II.

β. Sample size

Table 2

Weight gain (kg) of infants with different combinations of latrines and water usage<sup>e</sup>

		Latrine ownership		
		No	Yes	
Increased water group	No	-0.094 <sup>α</sup> (74) <sup>β</sup>	0.065 (22)	0.180 <sup>τ</sup> (-0.093, 0.453) <sup>δ</sup>
	Yes	0.029 (19)	1.177 (4)	1.106 (0.484, 1.728)
		0.150 <sup>τ</sup> (-0.250, 0.550) <sup>δ</sup>	1.031 (0.420, 1.642)	

α. Residual growth

β. Sample size

τ. Difference in weight gain

δ. 95 percent confidence interval

e. Factors included in the reduced model were: latrine, increased water usage, agricultural equipment, crowding, maternal literacy, frequency of maternal bathing, marital status, intervention group, and child age.

Table 3

Length gain (cm) of infants with different combinations of latrines and water usage<sup>e</sup>

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		Latrine ownership		
		No	Yes	
Increase water group	No	0.006 <sup>α</sup> (74) <sup>β</sup>	-0.207 (22)	-0.261 <sup>τ</sup> (-0.951, 0.429) <sup>δ</sup>
	Yes	-0.218 (19)	2.030 (4)	2.076 (0.559, 3.593)
		-0.309 <sup>τ</sup> (-1.005, 0.387) <sup>δ</sup>	2.028 (0.523, 3.533)	

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α. Residual growth

β. Sample size

τ. Difference in weight gain

δ. 95 percent confidence interval

e. Factors included the reduced model were: latrine, increased water usage, agricultural equipment, crowding, maternal literacy, mother knits/sews, mother brews beer, maternal pregnancy, frequency of maternal bathing, child sex and child's age.